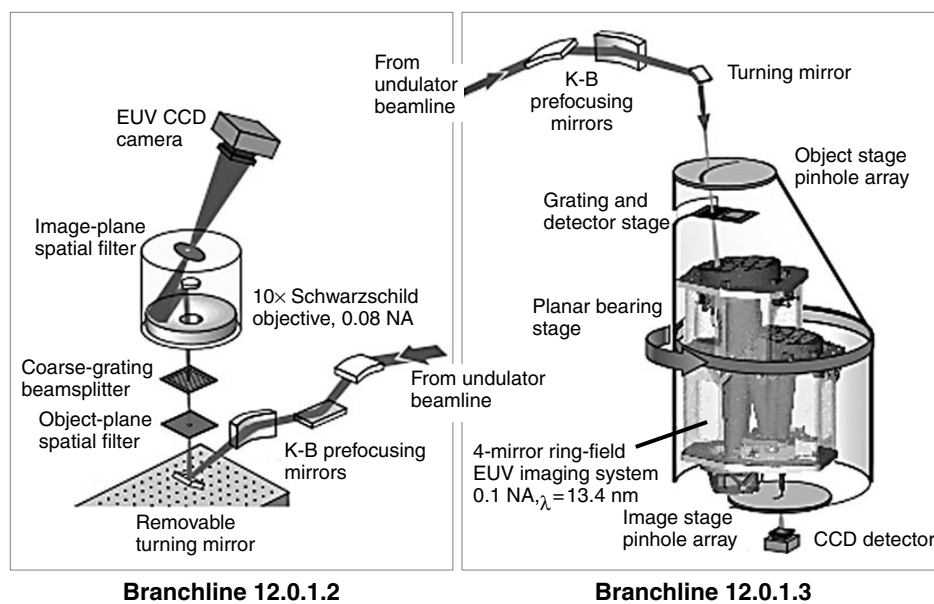


# Extreme Ultraviolet (EUV) Interferometry • Beamline 12.0.1

Berkeley Lab • University of California

## Endstation Specifications

Photon Energy Range (eV)	Photon Flux (photons/s/1%BW)	Spectral Resolution (E/ΔE)	Samples	Availability
60–320	~ $5 \times 10^{13}$ (@ 134 eV)	200–1000	EUV Optics ( $10^{-7}$ or $10^{-4}$ torr O <sub>2</sub> )	NOW



Schematic layout of the EUV interferometer endstations.

**B**eamline 12.0.1 contains two similar extreme ultraviolet (EUV) interferometry endstations dedicated to at-wavelength interferometric testing of EUV optical systems. Prototype EUV lithographic optics operating at a 13-nm wavelength are designed for imaging resolutions at and below 0.1  $\mu\text{m}$ . To achieve diffraction-limited performance, the surface figure and multilayer coating quality requirements of these systems must be in the subnanometer regime. The need for high-accuracy wavefront testing and system alignment have motivated the development

of interferometers with subangstrom accuracy over numerical apertures beyond 0.1.

The phase-shifting point diffraction interferometer (PS/PDI) utilizes the high coherent flux available from undulator Beamline 12.0.1 to coherently illuminate an optical system under test. Measurements on Branchline 12.0.1.2 have included several 10 $\times$ -demagnification EUV Schwarzschild objectives designed for use in EUV lithography experiments. More recently, Branchline 12.0.1.3 was constructed and successfully used for the measurement and

alignment of a four-mirror ring-field optical system. In both branches, glancing-incidence Kirkpatrick-Baez (K-B) mirrors focus the beam onto a submicron entrance pinhole spatial filter located in the test optic's object plane. At Branchline 12.0.1.3, the K-B mirror benders are controlled remotely, enabling both beam steering and fine alignment. Adjustable multilayer-coated turning mirrors oriented near 45° direct the beam at the proper angle for illumination of the test optic.

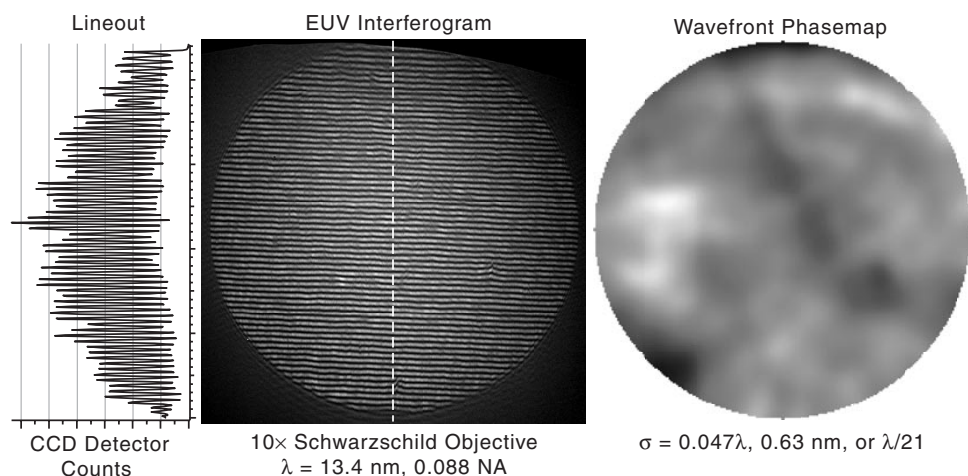
In the PS/PDI, a transmission grating beamsplitter placed between the entrance pinhole and the test optic forms a series of separable foci in the image plane. A patterned open-stencil mask in the image plane selects two of the beams for the measurement. The *test* beam passes through a relatively large window without attenuation and reaches an EUV CCD camera several centimeters away. A second beam is focused onto a pinhole that is smaller than the diffraction-limited resolution of the test optic, producing a spherical reference wavefront. The two

beams interfere at the detector and generate a fringe pattern that is analyzed to reveal aberrations in the optic under test.

The illumination wavelength and bandwidth are adjustable via the beamline's variable-line-space grating monochromator. The system is typically operated with between 0.1% and 0.5% energy bandwidth. A computer-controlled shutter is located just beyond the monochromator's exit slit for use with the CCD cameras or as a beamstop. In addition to the CCD cameras, several removable GaAsP beam detectors are available at various positions.

The test optic chambers operate at a base pressure of approximately  $10^{-7}$  Torr. As a carbon-contamination-mitigation measure, oxygen may be introduced through a needle capillary in each chamber.

All stages in the experimental system are driven by dc motors coupled from outside the chamber through bellows, or by vacuum-compatible Picomotors operating in the chamber. Motors are driven manually or by a computer interface. ■



**Analysis of an EUV interferogram** (center) recorded during the measurement of a 10× Schwarzschild objective. A lineout cross section (left) through the center of the image shows the very high fringe contrast observed. Analysis of the fringe pattern reveals small wavefront aberrations (right) present in this optic. The RMS aberration magnitude is shown. Data courtesy of K. Goldberg et al. (LBNL).

**This endstation is available to independent investigators with the concurrence of the PRT.**

#### For Endstation Information

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